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WHITE LEAD

FROM

MINE

TO

BATTLESHIP

By T. A. RICKARD

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ARRIVAL OF THE FLEET

[Editorial, MINING AND SCIENTIFIC PRESS, May 9, 1908]

NO ONE who watched the stately procession of battleships filing through the Golden Gate can have helped sharing the patriotic pride of the 800,000 people who waved a welcome from the many hills that look upon the haven of San Francisco. Yet there was a curious absence of noise; the bigness of the amphitheatre made the performers seem small and checked the applause of the onlookers. The size of the harbor of San Francisco was never more emphasized than when the American navy made its evolutions without being cramped for room and the whole countryside was lined with sightseers without being crowded. The immensity of the panorama checked applause, the thousands on the hillsides of the City knew that no shout of welcome could reach the sailors on the ships, so they stood silent, absorbed in the spectacle. The first signal was the faint boom of a gun off the Presidio. The smoke of it joined the low-lying fog that had threatened to mar the glory of the day. Soon the guns of Fort Baker on the Marin shore echoed the welcome, and the smoke almost hid the harbor entrance. Then in silent state the leading battleship glided through the Golden Gate, and at exactly equal intervals of four hundred yards the other gray men-of-war followed, each flanked by a dark torpedo-boat destroyer. The whole of the Atlantic fleet, comprising 18 battleships, advanced in single file, the westerly breeze blowing the smoke of their three-fold funnels ahead of them, so that it mingled with the salutes from land and water, flinging a murk of battle over the peaceful parade. The clouds hung low across the Contra Costa hills and big shadows darkened the water. Suddenly, as the flagship, the *Connecticut*, approached Alcatraz island and swung southward toward the inner harbor, the light broke through the

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clouds, the sunshine changed the dull gray hull into a radiant white vessel athrob with insistent life and assertive strength. And as the battleships moved into the sunlit space each of them seemed quickened into life and beauty. While the Atlantic fleet was entering the Bay, the Pacific fleet of 9 cruisers had stood at attention off Angel island, and at the proper moment they took their place in the procession, making an evolution the perfection of which even a landsman could admire. They swung into their allotted order, and thus the whole fleet of 18 battleships and 9 cruisers, with the torpedo-boat destroyers, and auxiliary vessels, came round the point into the anchorage that lies off the water-front of the City. Thus was completed a voyage of 14,000 miles which began on December 16, 1907, and ended on May 6, 1908, after a circumnavigation of the two Americas.

As the American fleet lies at anchor its presence here marks an event of manifold significance. To the business man the $200,000,000 of money represented by those floating arsenals is impressive in a financial way, to the townsman the 25,000 men on board represent a faithful body of defenders, to the patriot the feeling of proud possession in men and vessels is overwhelming. But beyond these obvious suggestions, other thoughts will arise to quicken the imagination. The arrival of this fleet punctuates a historic period; the path of empire has come westward at last, and the commercial importance of the Pacific Coast is conceded. Like Balboa, America stands silent on a peak of prophecy and looks across the waves of the Pacific, ready to fulfill her destiny. History moves fast in these later days. It is barely a century and a quarter since the first ship entered the Golden Gate; that was the *San Carlos*, commanded by Juan de Ayala, who passed through the portal of California on August 5, 1775. Likely enough the Spaniards, in exuberance of spirit, fired the old swivel gun on board the *San Carlos* as a salute to the land of

destiny. Thus the Mission of Dolores was founded on the sandy peninsula athwart the estuary of the Sacramento river. The mission of the *padres* belongs to an obliterated era, and yet only three lives separate their day from ours; some of the brave Argonauts who built their cabins near the old Spanish settlement and thus founded the modern San Francisco are even yet alive; so soon is history made: we count time not by the slow beat of the pendulum but by the quick throb of brave hearts. While the cities of the old world have scarcely changed and the highways of commerce across the Atlantic have been kept as of old, here within the space of a century and a half the Spanish dominion has been handed to a new people and from the sand hills washed by the Pacific there has risen a city, the expression of a commerce worthy the protection of a great navy. The San Francisco that rose to greet the squadrons of Admiral Evans was a city that has risen more than once. It is barely two years since disaster swept the seven hills of this City and abased a community of half a million people. No one who saw the crowds hurrying out of the lower town in order to get a spot of vantage from which to see the incoming fleet could fail to be reminded of that other exodus in April 1906. Two years ago today the many acres of broken brick and twisted iron lifted an ashen face to the blue of a pitifully perfect sky; today the same site is covered by splendid structures of steel and stone, traversed by orderly streets, and crowded with eager happy faces. So we of San Francisco give thanks for the arrival of this fleet and for much besides, accepting the event as a token of a happier day when San Francisco, guarded by the national navy, shall look as serenely across the interposing seas to the Orient as to the younger East of her Atlantic ancestry.

"The tumult and the shouting dies." Shall we forget? A people that built such a navy and a community that re-built such a city may well be proud of the outward and visible sign of national and civic

life. But shall we not hush our plaudits as we remember the mean and corrupt things done in our midst in the name of business. As nearly a million people stood watching the naval parade, was their subdued demeanor without significance? Despite justifiable national pride and personal pleasure in the event, some of them must have been touched with a deeper feeling; perhaps it seemed that the pomp and circumstance of the splendid procession was but a hollow show unless behind it all stood waiting the purified spirit of a patriotism that is unselfish rather than proud, that is willing to sacrifice personal gain to the maintenance of justice, and prepared to surrender the privilege of the one to the welfare of the many. Can a people be great and strong while yet corrupt and greedy? What is the relation of municipal debauchery to national manhood? Can we industrialize our lives without commercializing our souls? Or is it all a mistake, shall we say business is business, patriotism is sentiment, we must keep the two apart; an individual citizen or a community like ours can be undermined by municipal corruption, filthy politics, and strident incivism, and yet be a part of a national aggregate that shall be white as the hulls of the battleships and strong as the armored walls that guard the aggressive guns? The high steel buildings of San Francisco look down proudly upon the white steel ships at anchorage near-by. May either the buildings or the ships be effective in peace or war regardless of whether the men within them are moved by nobility of purpose or mere lust of life? Is patriotism only pride and civism merely self-assertion? Pardon this bombardment of questions; they are pertinent. We are grown men, not children. The irresponsibility of youth no longer becomes a nation that controls the destiny of the Pacific Ocean, and the reckless fun of a boy no longer befits the City that holds the keys of a national commerce. Let us not forget; let us play our part like men.

WHITE LEAD

[Editorial, MINING AND SCIENTIFIC PRESS, May 9, 1908]

BY WAY of celebrating the arrival of the American fleet in the Bay of San Francisco, we publish an article describing the series of technical processes by which the lead ore of the mine is converted into the white paint on the battleship. We take the reader to Idaho and show him the mine from which the lead ore was extracted, and then guide him mentally through the mill in which the ore is concentrated, to the smelter in which it is reduced, to the plant in which it is refined, and finally to the establishment in which the pure metal is converted into white lead ready for shipment to the Navy Yard. Thus the successive steps are described in detail, the effect being to emphasize the multiplicity of methods required to manufacture a single product and at the same time to link the miner and the sailor, demonstrating that the gleaming white paint comes from the dark places of the underworld and owes its existence to the skill of the men of the pick and gad, of the jig and vanner, of the furnace and refinery. No one who cares to contemplate the intricate series of processes involved in the fabrication of this one product will fail to be impressed by the ingenuity of mechanical device and the science of mining and metallurgical practice whereby the end is attained, suggesting the intricacy of the industrial foundation upon which modern civilization is based.

To the details given in the article itself, we may add that the hulls of naval vessels in commission are supposed to be re-painted at least every nine months, and those out of commission once a year. The approximate cost of painting a ship of the *Connecticut* class is $48,000 for labor and $27,000 for

material, making $75,000 in all. It will interest our readers to know that a naval vessel of 16,000 tons displacement will carry 12,000 tons of mild, wrought, and cast steel, also 500 tons of cast and wrought iron, also 200 tons of brass and 100 tons of bronze, besides 80 tons of copper. The lead and bearing-metal will weigh 200 tons; the paint and cement, 150 tons; together with 500 tons of ammunition. And all of this is furnished by the miner and the smelter, so that it is not too much to say that the American navy is the product of the American mine.

The photograph of the first-class armored cruiser *California* illustrates home manufacture, for this vessel was built by the Union Iron Works of San Francisco, as was the famous *Oregon*, which made so spectacular a voyage in order to reach the battle-line. As the *California* rides the quiet waters of the Bay of San Francisco, spick and span in her coat of white paint, the men of this Coast can afford to be proud, for she is the product of native industry. Despite her warlike purpose, this graceful vessel is almost feminine in the beauty of her lines, and to this suggestion is added the decorative and preservative touch of paint, enabling her to glory in the sunshine without fear of blemish, unlike the young women of an ancient day, of whom Martial said:

"The chalked Fabulla fears the pouring rain;
Cerused Sabella dreads the blazing sun."

Fabulla's powder might not be storm-proof, nevertheless, the white lead on the fair Sabella's face was not blackened by sunlight, but by sulphur. The men of Martial's time were evidently no chemists, but they had an eye for the beautiful in nature, assisted by art.

FROM

MINE TO BATTLESHIP

The Story of the Manufacture of WHITE LEAD PAINT

By T. A. RICKARD

[From the MINING AND SCIENTIFIC PRESS, May 9, 1908]

The original source of the white paint that protects the steel of the battleships now gathered in the Bay of San Francisco is the lead ore of a mine. The smart appearance of the serried squadrons is due to the pure pigment manufactured by a series of intricate processes from the mineral broken many hundred feet underground by the labor of the miner. From the dark and cavernous openings of the underworld has come the substance that now gleams in the sunlight of California. Many mines produce lead ore and many smelters extract the metal from its earthy matrix. The Selby smelter, at the northeastern end of the Bay of San Francisco, is the most important establishment of its kind on the Pacific Coast and it supplies the white lead used at the Mare Island navy yard. Of the mines from which ore is sent to the Selby works, the most important is the Bunker Hill & Sullivan in Idaho. It is my purpose to trace the lead ore from the mine to the smelter, and then to follow the lead from the furnace to the plant in which the white lead pigment is prepared, thence to the navy yard, where it is laid upon the sides of a battleship. It is the story of a complex industrial process.

Extraction in the Mine.

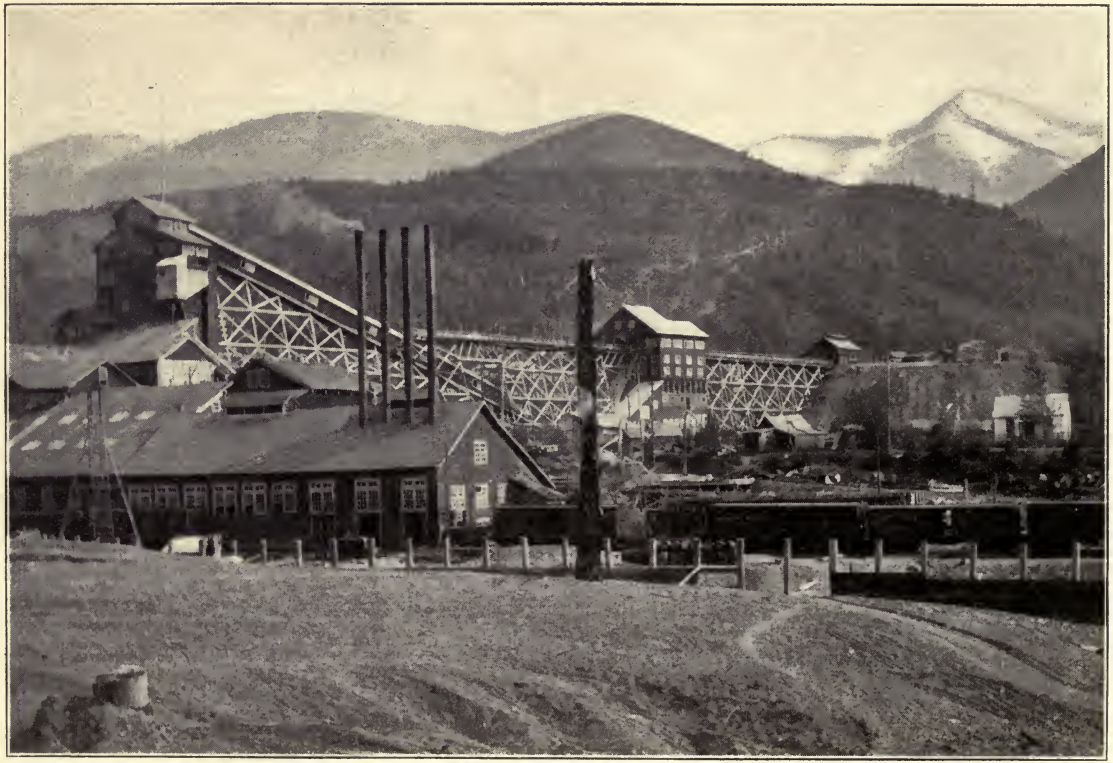
The Bunker Hill & Sullivan mine is the most important single lead-producing mine in America. It produces 40,000 tons of lead and 1,650,000 oz. of silver annually. Since its discovery this mine has paid $10,146,000 in dividends. The property is situated at Wardner, in the Coeur d'Alene, Idaho; it is a picturesque region, mountainous and forest-clad. To the picturesque in nature has been added the romantic in human history, and to these have been superadded the horrors and brutalities of industrial warfare, for in 1899 and for many years thereafter this locality was the scene of a bitter struggle against the worst forms of labor unionism. On April 29, 1899, the large concentrating mill of the Bunker Hill & Sullivan Mining & Concentrating Co. was destroyed by an explosion of dynamite, placed by rioters. The accompanying picture shows how the ruins appeared, and it will be seen that the only cheerful feature of the scene is the flag that floats undaunted at the top of the mill. It was hoisted after the explosion, when the troops came to restore order, for Frank Steunenberg, the Governor of Idaho, subsequently assassinated for doing his duty, had said that his purpose was "to bring Idaho back into the United States." Order was finally restored and Wardner became a peaceful settlement once more, but not before representative government had been severely tried.

This mining property, which became so famous by reason of the labor troubles and which later proved to be so magnificently productive, is a consolidation of many claims, the first of which was located in September 1885. From time to time, the territory controlled by the company has been increased by purchase, until now the group of claims covers about 3000 acres. From the very beginning the production of silver and lead has been almost uninterrupted; what stops there have been were due not to

any exhaustion of ore reserves but to unsatisfactory metal markets or to disturbed labor conditions. The productive zone of this property is known to be over two miles long and the deepest opening is 2200 ft. below the surface of the mountain into which the mine workings extend. The accompanying photograph shows the mill and the entrance to the main adit, which is named the Kellogg tunnel. It can be seen just above the small building on the right, and penetrates the mountain in the background.

The mine is said to have been discovered by a donkey, who strayed from his owners and was found standing on the ore; he had pawed the ground so as to remove the turf covering the outcrop of the lode. The incident is related in the judicial records of Idaho. Early in the history of the mine there was some litigation and Judge Norman Buck of the District Court said in his decision that: "From the evidence of the witnesses, the Court is of the opinion that the Bunker Hill mine was discovered by a jackass, Phil O'Rourke, and N. S. Kellogg; and as the said jackass is the property of the plaintiffs, Cooper and Peck, they are entitled to a half interest in the Bunker Hill, and a quarter interest in the Sullivan claims." In other words, it was decided that Cooper and Peck, merchants in the neighboring town of Murray, had grubstaked or outfitted Kellogg and O'Rourke.

The rock in which the ore is found is a very old quartzite, formed by the metamorphism of sandstone, which has been twisted, crushed, and distorted by geological movements. In the cracks and fissures formed by such movements, the lead ore has been deposited as galena, which when pure carries 86.6% lead, and 13.4% sulphur. With it is associated a nearly fixed proportion of silver, in the ratio of one ounce of silver to 44 pounds of lead. The parts of the mine from which the ore is extracted are irregular in shape, although the continuity of the lode and a certain rough alignment of the orebodies



Main Mill Buliding. Ore Breaker. Kellogg Adit.

The Bunker Hill & Sullivan Mine and Mill, at Wardner, Idaho.

The Bunker Hill Mill, Partly Reconstructed, After the Explosion on April 29, 1899.

within it have become emphasized by the operations of many years. When I visited the mine in 1904 the Kellogg adit was 12,000 ft. long and a new orebody had just been discovered at the face or eastern end. The quartzite appeared to be full of slips and fractures, which serve as local boundaries for the richer bodies of galena. A main foot-wall marked the southern limit of the ore-bearing zone, which had a dip of 50° southward. The galena replaces and impregnates the brecciated quartzite along channels created by the fractures extending along this foot-wall and away from it into the overlying rock. Fig. 3 is a sketch of one of the headings.

The photographs, taken by flash-light, will illustrate the appearance of the stopes where the lead ore is being extracted. These openings are from 100 to 140 ft. wide, and they have been made as long as 1500 ft., leaving cavernous spaces that would entail dangerous falls of rock if they were not filled subsequently with waste material, as the ore is removed in the course of mining. No less than 4,500,000 ft. of timber is used annually to sustain the ground and protect the workmen until the cavity or stope is filled with waste broken in cross-cuts and other exploratory openings of small size. Despite these precautions accidents do occur, although they are rarely fatal. Occasionally the mishaps to the miners lead to deeds of heroism and to the display of technical ingenuity in making a rescue. Thus only a month ago there was a collapse of rock separating a new stope from an older excavation overhead. On March 26, the rock between the two openings of the Kemp stope on No. 10 West, as it was known to the foreman of the mine, showed signs of caving. (See Fig. 2.) Two timbermen were sent to 'catch up' the caving ground and make it secure. The miners were withdrawn from the stopes. At 3 o'clock in the afternoon the ground began to cave badly, filling the manway and chute from the western portion of the stope and falling to the level below. An immediate

examination indicated that there was no apparent possibility of extricating the timbermen. Just as fast as the broken rock was drawn out of the chute and manway (C), to the No. 10 level, in endeavoring to clear a way to the place where the men were sup-

Fig. 1. The Coeur d'Alene, Idaho.

posed to be, the caved material would settle in the upper stope and induce a fresh collapse from overhead. To overcome this condition, long timbers were formed into a mat (A) and on this other timbers were piled in the upper stope, beneath the point (B) where the caving was worst. Then the material

was drawn as quickly as possible at the level below through the chute at C. Many hundred tons were removed and this caused the mat of timbers to descend. The ground continued to cave until the mat reached the top of the chute and manway, where it stayed, sealing these openings so that finally they could be emptied from below, and at the same time this mat of timbers afforded protection from the caving still in progress above. This was accomplished by 10 o'clock at night and the rescuers, climbing up the manway, found one of the timbermen a short distance from the head of the passage and pinned in a narrow space (X) between masses of rock and timbers, yet enough to one side to have escaped being crushed by the descent of the rocks that had swept down the manway and chute. He had been in the greatest danger and would inevitably have been killed had any other method been adopted. This man stated that his comrade was in a small drift (Y) leading from the stope, now completely sealed by the fallen rock. It was decided that to drive through the cave and the mat of timbers was impracticable, the entrance to the drift being above the timbers. Therefore the manager, who led the rescue-party, decided to make a passage through solid rock from the top of the manway. Communication with the imprisoned man was established by an air-hose, which happened to be connected to a machine-drill standing in the drift close to the timberman, and by actual conversation through this tube it was ascertained that he was unhurt and had plenty of air. Blasting had to be avoided, although the ground was "quite stiff," on account of ventilation for the rescuers and for the imprisoned man. The shock of a blast was pretty sure to start more caving. So the entire distance of 15 ft. was cut out by Waugh stoping-drills, fitted with a chisel-bit. In 17½ hours the rock was cut out in blocks and the interior drift was reached, the man being taken out at 7:30 in the evening, after

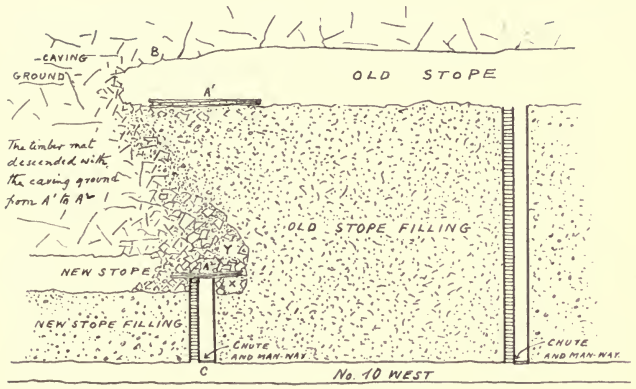


Fig. 2.

facing death for 28½ hours. Thus even the lead that yields the white paint on the battleship in San Francisco bay is not without incidents as thrilling as those of naval warfare, and not without the exhibition of a resourceful courage such as an admiral might envy. For the manager of the mine, Stanly A. Easton, worked without cessation for 29 hours.

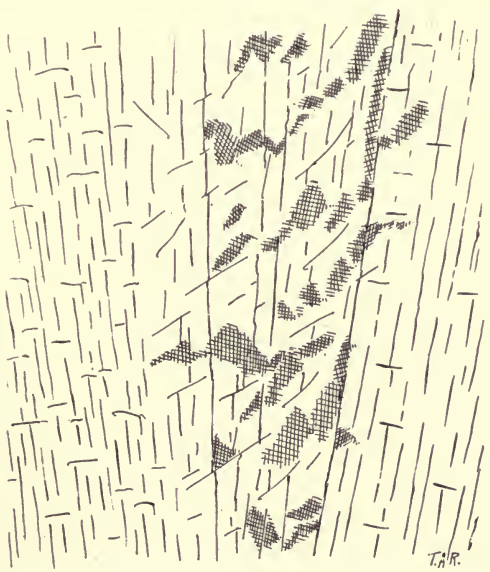


Fig. 3.

directing the rescuers and leading the way to the rescue. And when it was all over and the two timbermen were safe in their homes, he wrote to the president of the company thus:

"This gives a new application for the useful Waugh drill. One machine did practically the whole work, running constantly for fifteen hours, there being relays of four men, who practically held the drill up to the face for its work with main strength, in the same manner as coal punchers are handled. The ground was too hard for any progress to be made through it by picking and moiling, and what would ordinarily be called stiff blasting ground. I am writing you complete details of this incident as you will no doubt see Associated Press despatches concerning it and also as there were certain methods used which, so far as I know, are entirely novel and which proved in this case to be exactly the right thing to do. The situation was a nasty one and we are mightily well pleased that both the men are safe and sound, which is due principally to the hard work of the miners in carrying out the plans agreed on by Mr. McDougall, Jones, and myself. It took just 28 hours of solid work to carry the thing through. The damage to the stope is insignificant, as the broken material is practically all waste from the hanging wall and no ore is either buried up or lost. The organization of the crew is disturbed for two days, but the output of ore seems to have fallen off but very slightly."

If the American fleet has many men like this, it ought to ensure America from invasion!

In the course of my examination of the mine in 1904 I walked through 4½ miles of workings. The additional work since that date has increased the length of the main workings to 6 miles, including the Kellogg tunnel, which is nearly 2½ miles long. Through this adit, which took 8 years in construction and cost over $200,000, the ore is hauled, by electric locomotives, to the mill. Every year, through the portal of this mine, there is brought enough ore

to provide every man, woman, and child in the United States with one pound of lead, and even then there is some left over. Besides serving as the main entrance or adit of the mine, the Kellogg tunnel serves to ventilate the workings by connection with other and higher drifts and shafts penetrating the ground overhead. The mine is well ventilated and this is particularly necessary where lead ore is being handled, for lead is poisonous to the human system. However, the men rarely suffer from contact with it, immunity being due principally to the fact that the metal, when occurring as galena, the sulphide, is in an insoluble form and is not readily assimilated by the body. Furthermore, the dust is mitigated by sprinkling dry drifts, so that cases of lead poisoning are only at the rate of one or two in 10 or 15 years, among 500 employees. Sanitary precautions are strictly enforced. About 80% of the men working in this mine are native born Americans, although many are of Cornish descent, their forefathers having been miners for many generations. Of the entire force nearly 60% are married and many own their own homes at Wardner and Kellogg, the adjacent towns. The Bunker Hill & Sullivan has been in operation so long that many of the miners and foremen have worked in no other mine.

At the time of my visit I watched the methods employed in breaking the ore. A sollar or platform, made of 3 by 10 in. boards, is laid on the floor of the stope and the ore is broken down upon this, some fine waste being spread on the boards to protect them from the blast. Machine-drills are used to drill the holes, which are 7 to 10 ft. deep, 2 in. diam., and loaded with gelatine dynamite, exploded by a cap to which a fuse is attached. After blasting, the larger pieces of quartzite are removed by hand (to be used as filling) and the remainder is shoveled into chutes or mill-holes, 25 ft. apart and lined with round poles, 6 in. diam. at the small end. These chutes lead from the stope-floor down to the level,

through the stope that has been already excavated and filled. At the level the ore is drawn into cars, each of 3 tons capacity, formed into trains, and hauled by electric locomotives. The ore is stoped for its full width, so as to explore as well as extract. Ordinary drifts might go through almost barren ground within the core of an orebody. Fortunately the barren quartzite breaks in blocks while the lode shatters into small pieces, so that the larger fragments of waste are easily picked out for filling, while the ore is collected into chutes. If the output of a stope is hurried so that the rock broken is not turned over carefully and the lead gleaned before the next blasting, there is a loss due to burying the lead under quartzite. There is also an inevitable small loss through the galena left on the faces of rock that is retained as waste, and there is a loss from the pulverization of the mineral by blasting and breaking, but usually less than one eighth of 1% goes into the filling. Rarely a piece containing 2% may be lost and also some galena dust. The waste is occasionally drawn from one stope to another and is then examined. The presence of a trace of moisture lessens the dust arising from the broken ore. In fresh rock the ground appears dry, but after a while the moisture exudes. This water is not acid; it contains iron in solution, derived from siderite, the carbonate of iron, which occurs in adjacent veins. At the surface the water from the mine precipitates iron hydrate, which dehydrates to ferric oxide.

The accompanying sketch shows the face of a small stope, the quartzite being more thinly laminated on one side than on the other, and with a different dip. The dark lead ore crosses the laminations of the zone of fracture in an irregular way. (See Fig. 3.)

After a visit underground, I climbed through old workings to the surface and saw the place where the lode was first discovered. The site is marked by a big open-cut situated close to the line of the Stemwinder claim. An outcrop of galena was found here

Getting Ready to Blast Big Pieces of Ore.

and as the ridges of quartzite were prominent they were assumed to be veins, although, as was proved later, the lode crosses them at a strong angle. In consequence of the first mistake, the claims were located across the strike of the lode, so as to cause numerous lawsuits arising from the interpretation of

In a Stope of the Bunker Hill & Sullivan Mine.

extra-lateral rights. As seen in the open-cut, the lode is a strong cross-fissure cutting the bedding of the quartzite along a sheer-zone marked by brecciation. The most prominent structural feature is the foot-wall, which limits the mineralization northward. The lead ore occurs within this sheer-zone, along the foot-wall, along the fractures that are roughly parallel to the foot-wall, and in irregular masses having a course that appears to be determined by the bedding planes of the quartzite, which, being shattered and disordered near the main line of fissuring (that is, the foot-wall) produces a confused mineralization, tending to more evident shape and direction westward as the orebodies extend away from the foot-wall. While standing at the point of discovery I found a piece of quartzite showing beautiful ripple marks, indicating that the metamorphism to which the rock had been subjected has not been able to obliterate the traces of sedimentation. The sight of those ripples, fixed in the hard quartzite that encloses the valuable ore, took my imagination back to that remote geological period, many million years ago, when the shallows of the Algonkian sea were ruffled by a gentle breeze, leaving its imprint indelibly recorded on the soft sand from which the alchemy of nature had fashioned an adamantine rock, now laboriously penetrated by man in his search for metallic wealth.

Treatment in the Mill.

From the mine the ore goes to the mill, where it is crushed, classified, and concentrated, so as to get rid of the worthless matrix of quartzite (and some siderite) and collect the valuable minerals in a clean and marketable material. Argentiferous lead, in the form of galena, constitutes the chief product, but there is also the iron pyrite, with which silver is associated in the final concentrate. The problem is to save the lead and silver without the zinc.

The electric locomotive pulls the cars (holding 7000 lb. apiece) to large storage bins; there the ore

falls over grizzlies (parallel inclined steel bars 1¼ in. apart), the oversize going to a Comet crusher, size D, of the gyratory type, of which there are two, one being held in reserve for such times as repairs are needed. By this machine the ore is crushed to a maximum diameter of 2½ in. and then spills onto a horizontal picking-belt, where a couple of men are stationed to pick out the clean ore (galena) and the inevitable mine rubbish by hand. This belt delivers to roughing rolls, and from them, after being reduced to a size of about 40 millimetres, the ore is discharged onto an incline belt-conveyor. Here it is joined by the undersize, which passed between the bars of the grizzly and is brought thither by another belt-conveyor.

The joint product is now carried to the top of the mill proper, a height of 100 ft. in a horizontal distance of 300 ft. There it is fed into a Vezin sampler, the sample extracted passing to another sampling machine of the same kind placed immediately underneath. Each sampler takes one tenth, so that one per cent of the whole is finally obtained. This sample is reduced and prepared for assay daily.

After sampling, the ore drops into the mill bins, which have a capacity of 600 tons, equivalent to a 12-hours supply. From the bins the ore passes through a pair of trommels, or revolving cylindrical screens, one for each of the two units into which the plant is divided. The upper section of each trommel has round holes of 18 mm. diam., while the lower section has holes of 36 mm. The oversize from the upper section goes to rolls (placed at the bottom of the mill) and is re-ground by other rolls, before being returned (by a bucket-elevator) to the same trommel. The size larger than 18 mm. but smaller than 36 mm. goes to the bull-jigs, which produce the three usual products, namely, concentrate, middling, and tailing. The first is shipped to the smelter. The middling is re-ground by rolls to the next size, the trommel sizes being 36 and 18 mm., as stated, fol-

lowed later by 10, 7, and 3 mm. openings. At each stage of the re-grinding by rolls, the product is screened through these trommels, to be treated by jigs, until finally it gets below the 3 mm. diameter. After this reduction the middling from the remaining concentration processes is re-ground by Huntington mills, instead of rolls. The classification of the re-ground product (now less than 30 mesh) from the Huntingtons is effected in two ways, namely, by spitzkasten or pyramidal boxes, and by Callow settling-tanks. The overflow from the last goes to Frue vanners, while the underflow passes to Wilfley tables.

The finest revolving screen (or trommel) has apertures of 3 mm. diameter and after the crushed ore has passed through this, it is hydraulically classified, the sand being concentrated on jigs while the slime is conducted to a settling-tank, from which it is drawn for treatment (together with the re-ground product coming from the Huntington mills) on Wilfley tables and vanners.

Middlings from the 10, 7, and 3 mm. jigs, together with all the tailings from the sand-jigs, Wilfleys, and vanners, are carried by launders to the annex, where they are classified and dewatered by Callow screens, the oversize (above 26 mesh) being re-ground in Huntington mills, while the undersize is re-treated on Wilfley tables and vanners.

Among the principal features of the mill may be mentioned the re-crushing by rolls, the passage of the coarse middlings through the rolls, and the grinding of the fine middlings in Huntington mills. Water is used to wash the vanner concentrate into an orifice (at the bottom of the front boxes) leading to the bins. The end treatment, after classification, consisted, at the time of my visit, of four sets of jigs, the overflow from which went to settling-tanks, the middling from these finishing jigs being ground in Huntingtons while the fine overflow passed to Frues and the coarse overflow to buddles, followed by Wilfleys. The buddles are now no longer used and

Callow screens form an important feature in the equipment. Card concentrators are now being tested, with promising results. It has been suggested that a filter-press be employed to catch the fine galena carried in suspension in the mill-water; the result of such an experiment will be awaited with interest.

Map Showing Position of Selby Smelter Relative to San Francisco.

In March of this year the mill treated 30,600 tons in 28 working days. The ore assayed 12.56% lead and 5.07 oz. silver, so that the material treated contained an aggregate of 7,686,720 lb. lead and 155,142 oz. silver. The ratio of concentration was 4.6 into 1.

The yield, as determined by sampling and fire-assay, was:

Class.	Weight, Tons.	Lead, %	Silver, Oz.
First	1,169	76.8	28.6
Second	2,866	50.3	18.2
Slime	1,097	44.9	18.0
Middling	1,448	10.3	4.2
Total	6,580	45.3	17.0

Thus there was extracted 5,965,096 lb. lead and 111,598 oz. silver, the total recovery being 79.4% of the lead and 71.9% of the silver, or 77.6% of the total lead and silver in the ore. Of the above mill-products, only the middling is re-treated, the others are shipped to the smelters at Tacoma (Washington), Selby (California), Pueblo and Denver (Colorado), Perth Amboy (New Jersey), and occasionally elsewhere. In the mill, 52 men are employed; the total cost of milling in March per ton of crude ore was 35.9 cents; this cost for many years did not exceed 21 cents per ton, and it has been increased by reason of the more complicated treatment adopted in order to obtain a higher extraction.

Besides the different concentrates saved in the mill, the mine yields a varying amount of selected ore, picked in the stopes and at the top of the mill, as previously described; this is shipped directly to the smelters. The proportion of this product sold from month to month depends upon the condition of the market. In March 250 tons only was shipped; this contained 58.8% lead and 19.2 oz. silver per ton. There have been months when as much as 3000 tons of such ore was sent to the smelters. The cost of producing lead, laid down at New York, in March. was 2.3 cents per pound. In the year ending March 31, 1907, the Bunker Hill & Sullivan Mining & Concentrating Co. mined and milled 336,630 tons of crude ore, the cost for stoping being $1.47; for exploration, 9.4 cents; for improvements, 30 cents; tramming from mine to mill, 7 cents; concentration, 25.5 cents; shipping expense, 5.1 cents; general expenses,

19.5 cents, the grand total for all operating costs being $2.438 per ton. The railroad freight, together with smelter charges (direct and indirect), amounted to $5.16 per ton of crude ore. The freight ranges from $4 per ton to Tacoma to $8, which is charged to Selby and Denver. On ore and concentrate, as shipped, the total cost of freight and smelting is $19.61 per ton—the mill product being, as we have seen, a concentration in the ratio of a little over 4½ into 1.

Such ore and concentrate as is sent to Selby, is transported by rail to Portland, by way of Tekoa, and thence over the Shasta route to Vallejo Junction, where the Selby smelter is situated. The distance from the mill to the smelter is 1150 miles.

Smelting the Ore.

The works of the Selby Smelting & Lead Co. are a mile from Vallejo Junction and 29 miles from San Francisco; they were founded in 1868 by Thomas Selby, a pioneer hardware merchant of San Francisco. In 1864 Selby built a shot-tower on the corner of First and Howard streets, where it stood until the earthquake-fire. He imported his lead from Spain and England; and finding this both awkward and costly, he conceived the idea of treating the lead ores yielded by the mines of the Pacific Coast, and started to make his own lead in 1868. After his death, in 1875, the business was incorporated, A. J. Ralston becoming president and H. B. Underhill, Jr., secretary, of the Selby Smelting & Lead Co. In 1905 the control was sold to the American Smelters Securities Corporation, and Mr. Underhill became president. The operations of the plant are varied, and the importance of the works may be gauged by the fact that they refine $25,000,000 worth of gold and 12 to 15 million ounces of silver per annum. The smelter gets a variety of products from different localities, but its chief supply consists of the argentiferous lead ore from Idaho and the silicious gold-

silver ores of Nevada. The Bunker Hill & Sullivan mine sends crude ore, 'bull-jig' concentrate, fine concentrate, and slime. The last of these has to be briquetted before being smelted, so it is first mixed with fine roasted ore and silicious material (from Tonopah or Goldfield); slaked lime is used as a binder, the briquetting being done in a Boyd press. The bricks from this machine, after drying, are ready for the blast-furnace.

Since the ore supply at Selby is usually irregular and the material smelted rather high-grade, it is not expedient to carry large stocks or to form bedding-floors. From the bins the ore and concentrates are taken to the feed-floor, where they are shoveled by hand into the blast-furnace. This is 36 by 144 in. at the tuyeres. The blast is under a pressure of 33 to 34 oz. per square inch. From 130 to 140 tons of charge is treated per day, exclusive of fuel and slag. Of the charge 60 to 70% is ore. It is aimed to have 15% of lead on the charge. The Bunker Hill product usually constitutes about one-sixth to one-seventh of the whole, the other lead in the charge coming from roasted matte and refinery by-products. The charge consists of:

Lb.	Description and Source.
2,500	Briquetted slime (Bunker Hill), fine iron and silicious ore.
1,100	Roasted matte.
1,000	Limestone (Santa Cruz).
800	Silicious ore (Tonopah or Goldfield).
800	Lead ore, as 'bull' jig concentrate or crude ore (Bunker Hill).
300	Refinery by-products, mainly litharge.
200	Metallic iron (San Francisco).
1,000	Coke (Australia).

This makes 7700 lb. altogether, to which 20% of old slag is added, making 9250 to 9500 pounds.

The roasted matte contains 12% lead, 12% copper, 45% iron, 3% zinc, and 7% sulphur. The slag is

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returned mainly in order to regulate the physical condition of the furnace and to correct irregularities in its operation. It is the aim to make a slag of the following composition:

%		%	
31	SiO_2	18.5	CaO
35	FeO	7	Al_2O_3

The alumina comes in the silicious ores from Nevada. The slag also contains 1.5% MgO from the limestone, 1% Pb, 1 to 1.5% S, and 2.5% Zn, besides traces of copper, antimony, phosphorus, etc., in fact, minute traces of most of the elements.

The limestone is the reject from the portland cement works at Santa Cruz. The fuel is coke, usually from Australia, coming from Newcastle, in New South Wales; but coke from Alabama and Utah also is used at Selby. The silicious ore is the rich stuff mined at Goldfield and Tonopah, in Nevada. On the day of my last visit to the Selby smelter, they were sampling a carload of ore from the Little Florence lease. This ore contained 15 to 25 oz. gold per ton and in hand specimens the dull yellow streak of very fine gold could be seen traversing the dark flinty quartz. Such stuff requires most careful sampling; the shipment is sampled by hand, one shovelful going to the sample, the next to the reject. The iron required to make a fusible slag is provided by scrap bought from junk-dealers in San Francisco. This scrap iron is bought for $9 per ton and it includes heterogeneous remnants of a curious kind, gathered from the ruins of the great conflagration that almost destroyed San Francisco in April 1906. In the strange assortment sold as flux to the Selby smelter are sewing machines, type-writers, old rifles, stoves, girders, electric motors, bolts, cables, spikes, frying pans, chains, pipe fittings, every form of iron likely to be used in a big city. I saw a whole stack of frying pans melted together by the fierce fire that followed the earthquake; there were lumps of ag-

glomerated spikes, and chains that had lost their shape. The smelter will buy nothing longer than six feet, so any cable, channel iron, or the like, has to be cut before shipment to Selby. It would fall cross-wise in the furnace and prevent the charge from settling properly. Among the scrap piled in the smelter yard there were pieces of structural material such as channel iron and girders, and I noticed that in many cases the iron was melted with pieces of masonry so that they formed an artificial iron ore. Thus the ruins of San Francisco are used in the making of the lead from which the paint on the battleships is fabricated.

When once in the blast-furnace, the charge takes six hours to be smelted. The separation of lead from the matte and slag takes place within the furnace, the lead being drawn off through the Ahrents syphon-tap. The matte and slag run out into a rectangular settler or fore-hearth, which is on a truck, so that the slag being lighter overflows into the slag-pots, each of which holds two tons and is drawn to the water-front by a small locomotive, to be discharged into the Bay.

The matte is tapped from a lower level (of the fore-hearth) into a series of pans on trucks; after cooling, the matte is broken by sledge-hammers, then crushed, roasted, and returned to form part of a subsequent charge. When the copper accumulates in the matte beyond 16%, a further concentration is effected by smelting a charge of matte, silicious ore, and limestone, so as to get a product containing from 45 to 55% copper. This is first roasted and then leached with the sulphuric acid liquor from the parting-room, the result being to make a bluestone (copper sulphate), which is sold to wheat-growers to kill 'rust' and to the Western Union Telegraph Co. for use in gravity cells. Some of the bluestone goes to Mexico to be employed as a chemical in the old patio process.

The matte and the pyritic ores are roasted in Ropp furnaces, the invention of the former superintendent, Alfred Von Der Ropp, a Russian nobleman, now residing at Geneva, and as well known for his long and skillful management of this smelting establishment as he is affectionately remembered for his unfailing humor and courtesy. There are four of

The Selby Smelter and National Lead Works.

these roasting furnaces; three of them are 90 ft. long, and one of them is 150 ft. They are provided with a traveling mechanical rabble, operated by a cable that passes over a sheave at the upper end of the furnace, so that the rabble is outside of the furnace half the time, during which it is being cooled. This is one of the occasions when a nobleman got the best of the rabble.

Returning to the blast-furnace; the lead flows from the well into moulds and is cast into bars weighing 100 lb. apiece. These are taken on trucks to the refinery and there elevated to the upper floor.

Here are the liquating kettles. Liquation or eliquation is the process of separating metals by the difference in their melting points. The lead from the blast-furnace contains copper, antimony, and other metals, the presence of which interferes with its industrial utility; hence the necessity for liquation. There are four kettles for this purpose, arranged in pairs, each pair holding 60 tons. The impure lead is melted at a minimum temperature, about 710°F; at that temperature the copper comes to the surface in the form of dross, which also holds some antimony. A press is hung from a crane into the molten metal within the kettle and the dross is skimmed into this press, where, under a compression of 90 lb. per sq. in., the free lead flows back into the kettle, while the coppery dross (containing some antimony) remains. After 10 or 12 hours the dross will have been skimmed and the lead, now free from all but a trace of copper, is syphoned into a reverberatory called a 'softener,' where the temperature is raised and the remaining antimony driven off by volatilization and oxidation, chiefly the latter. The result of this operation is to put the antimony into the litharge that is skimmed from the surface of the molten lead; these skimmings are run through another smaller reverberatory with a charge of coke and galena and some of the copper dross from the liquating kettles; the result is a yield of copper matte and base bullion containing some of the antimony, the major part of which is collected in a slag assaying 35 to 40% antimony and 62 to 58% lead. This slag is re-smelted so as to yield an antimonial metal, which is sold to the Mixed Metals Co. at Omaha and elsewhere, to be used in making type metal, solder, babbitt, and other alloys of which antimony is a necessary constituent.

When the charge in the softening furnace is 'cooked,' that is, all the antimony, arsenic, and other impurities eliminated, the lead is tapped into desilverizing kettles, 3 ft. deep and 10 ft. diam. There are four of these and they hold 60 to 65 tons each.

They are made of cast iron and are fired by oil (as are the other furnaces and kettles in the refinery building) brought from Bakersfield, California. The oil is pumped from the Union Oil Co.'s works, 1¼ miles away, to the tanks at the smelter. This oil is pumped from Bakersfield to the oil works, a distance of 300 miles. When you pass the Selby smelter as

In the Refinery. Reverberatory Furnace, Moulding-Kettle, and Moulds.

a passenger on the overland train and notice a most disagreeable sulphurous smell, don't blame the furnaces in the works you are passing, debit your discomfort to the oil refinery which is to windward (for the wind usually blows from the west) and so happens to reach the traveler just when the train is alongside the smelter. Blame Rockefeller, not Guggenheim. And, on second thought, don't blame even Rockefeller, for he has enough to his charge, including a $29,000,000 fine, for the Union Oil Co. is the one genuine competitor of the Standard Oil.

In the desilverizing-kettles, the temperature is raised to a point where a slab of zinc melts readily in the liquid lead; this is at 840°F. The zinc unites with, and collects, the silver. This is the old Parkes process. Sufficient zinc is added to desilverize the lead and as the zinc melts it is mixed, by a mechanical stirrer, into the bath of lead. The scum of zinc that begins to rise to the surface contains the silver, and gold also, which desert the lead for the zinc. It is a concentrating process. The lead as delivered into the kettle will contain 255 oz. silver and 15 oz. gold; the zinc scum, after being pressed, carries 3000 to 3500 oz. doré, this last being the smelterman's term for the two precious metals when mixed in unrefined bar. Literally, it means golden. Any copper remaining over from the preceding treatment is also collected in this zinc scum. The scum is squeezed in a Howard press so as to extract any uncombined lead. The pressing machine is lowered by a crane into the metal bath and when the press has acquired the temperature of the lead, the scum is ladled into the press. Formerly it was the practice to remove the scum and liquate it, but this has been obviated by the introduction of the press, which was invented by W. H. Howard, formerly at Pueblo and now at the Garfield smelter, in Utah. After being pressed, the scum contains 22 to 24% zinc, 10% precious metals, 3% copper, the rest being lead. The scum looks like the native silver, slightly tarnished, to be seen in mines, as in the Mollie Gibson at Aspen. The molten lead in the kettle resembles mercury, though it is less mirror-like and of lighter lustre. The final scum on the surface of the lead is collected by a wooden rake (which chars, but does not burn) and is lifted out by a flat ladle.

The lead is now free from gold and silver, but still contains some zinc, say 0.5%; it is syphoned to a reverberatory furnace on the ground-floor. This syphoning of molten metal is interesting. It is done by means of a 2½-in. iron pipe bent into U shape with

one leg longer than the other. This bent pipe is laid in the bath of lead (within the desilverizing-kettle) until both have the same temperature; then the stop-cock at the lower end is opened and hot lead fills the syphon; the stop-cock is closed; two workmen manipulate the syphon (now full of lead) with tongs and hooked rods so as to get the syphon out of the bath without breaking the column, keeping the end of the short leg within the bath; when the syphon is finally put in place, the stop-cock is opened and the lead runs into the furnace below.

This furnace has a capacity of 70 tons. Here the lead is subjected to an oxidizing heat whereby all the remaining zinc is driven off, partly by volatilization and partly by collection as oxide in the litharge that is formed; this litharge is skimmed and resmelted in the blast-furnace.

Next the lead is tapped into the moulding-kettle, which holds 60 tons, and serves the purpose of maintaining the metal at a suitable temperature while it is being tapped—by a syphon again, but a much smaller one—into 50 moulds, set in three-quarters circle. Each of these moulds yields a pig weighing 100 pounds. As thus refined, the lead is taken to the white lead plant.

But before tracing the conversion of the metal into paint, we must return for a moment to the treatment of the by-products of the refinery. The zinc scum (from the desilverizing process) containing the gold and silver is placed in graphite retorts, to which condensers are fitted. By this process of distillation, the zinc is collected in metallic form, while the precious metals remain in a highly concentrated lead running 4000 to 6000 doré. This rich product goes to the cupelling furnace, where the lead is converted into litharge (which is sent to the blast-furnace), while the doré bar is reserved for the parting-plant. Here the silver is separated by being dissolved in strong sulphuric acid, the resulting silver sulphate being precipitated on copper, leaving a

copper-sulphate solution (still containing free acid) that is used for leaching the high-grade matte, as previously related. The liquor from the condensation of the fume escaping from the parting-kettles has a cherry red or ox-blood color due to the presence of selenium, derived from selenides in the Tonopah and Goldfield ores. This gold and silver selenide is converted to a hydrogen selenide and is then reduced by the action of the sulphur dioxide, generated by the solution of the silver in sulphuric acid. The gold remains in the dissolving-kettle as a brown powder; this is washed thoroughly, and then melted in graphite crucibles, to be sent to the mint at San Francisco. The silver, precipitated on the copper, is washed, pressed into cakes, melted in a small reverberatory, and cast into bullion bars. The silver bullion is put in a vault while still hot, as also is the gold. When placed in orderly array within this vault, these beautiful bars of precious metal impress the visitor as tokens of the wealth of Idaho and Nevada, the two contributory States. The silver is sold to the various United States mints, but most of it is exported to Hongkong, for use in China.

We have traced the lead to the last stage of refinement. In an adjacent building some of it is made into sheet-lead, for lining tanks exposed to acid liquors, and in another building at Selby the metal is made into shot of various sizes, put into cartridges, and made ready for those who shoot the ducks and geese so plentiful on the estuary of the Sacramento river and elsewhere in California. The lead is also used in making pipe for sanitary purposes and for encasing underground electric wires. For such purposes it is being used in steadily growing quantities, for it admits of being twisted and bent as iron does not. But our interest at this time is its conversion into white lead to be used as a pigment. This is done at Selby in a plant alongside the refinery, from which we have seen the lead issue purified of all its other metallic associates.

Conversion of Metallic Lead Into White Lead.

Metallic lead in its purest form is used for making white lead; indeed, in the trade, 'corroding' lead is used as a synonym for purity. White lead results from the corrosion of metallic lead; the process involved is comparable to the rusting of iron, which yields a characteristically red product, just as the similar oxidation of lead gives a white substance. But the conversion of metallic lead into white lead is more than a process of oxidation, it involves both carbonic acid and water, so that it includes carbonization and hydration. White lead is a compound of lead carbonate and hydrated lead oxide, the formula being $Pb(OH)_2.2PbCO_3$. It is valuable as a pigment because it is dead white; any impurity in the original lead or any impurity introduced during the process of corrosion is apt to discolor the product; therefore, the manufacture of this substance demands the greatest care to eliminate every source of contamination prejudicial to a pure white.

The lead comes from the refinery in the form of pigs weighing 100 lb. apiece. The Selby plant manufactures 2500 tons of white lead per annum and this requires about 2100 tons of the 'blue lead,' as the pure metal is termed. Four or five tons of lead are melted in a kettle. The molten metal runs out through a divided spout forming a steady double stream; this flows upon an endless chain made of a double series of moulds, each 6 in. wide, resembling waffle irons. The chain is long enough so that when the molten metal reaches the end, the lead has chilled and the perforated discs or 'buckles' fall in a pile ready to be transferred to the 'stacks'. The 'buckle' is a disc of lead $\frac{1}{8}$ in. thick, so perforated as to expose a large surface to chemical action, as shown by the accompanying sketch (Fig 4).

A 'stack' is a series of earthenware pots holding the blue lead while it is being converted into white lead. The pots are arranged in 9 tiers separated by

layers of tan, the whole structure occupying a space 20 ft. square, to a height of 20 ft., within a wooden building, arranged in suitable partitions, the sides of which are built up or taken down, board by board, as circumstances require. In the pots the lead is placed so as to be exposed to the corrosive effects of acetic acid. The acetic acid comes from New York; it is made from lime acetate. Wine vinegar might be obtained in California, of course, but it is too expensive for the purpose. Each pot is (as shown in Fig. 5) 11 in. high, the upper portion being 7 in. diam. and the lower 4½. The pots are made by the Steiger Pottery Co. at Baden, on the southern outskirts of San Francisco. The lower part is filled with acid; the shoulder, formed where the pot widens, carries the buckles, which are thus exposed to the fume without actual contact with the acid itself. If the lead were immersed in the acetic acid, it would be dissolved completely without forming white lead.

In building a 'stack', first a layer, 2 ft. thick, of 'spent tan' is laid down. This is the tan bark discarded from a tannery after all the tannin has been extracted. The tan used at Selby comes from Benicia. On this bed of tan a layer of pots is arranged in 27 rows of 27 each, or 729 altogether. The lower portion—4 in. deep—of each pot is filled with a pint of acetic acid; then the buckles are placed on the shoulder; there are 17 of them, weighing 15 to 18 lb. to each pot. In order to expose a maximum surface to the vapor, the buckles are not laid flat, but are crumpled. On the top of the tier of pots, now filled with lead and acid, separately, the workmen place boards, overlapping so that every crack between any two of them is covered by another board. The purpose is to prevent the tan on the floor above from falling through chinks into the pots of the tier underneath, for this would spoil the white lead. Thus tier after tier is built, the succession of tan, pots, and boards being repeated 9 times. On the top, as on the bottom, a layer of two feet of tan is packed solidly

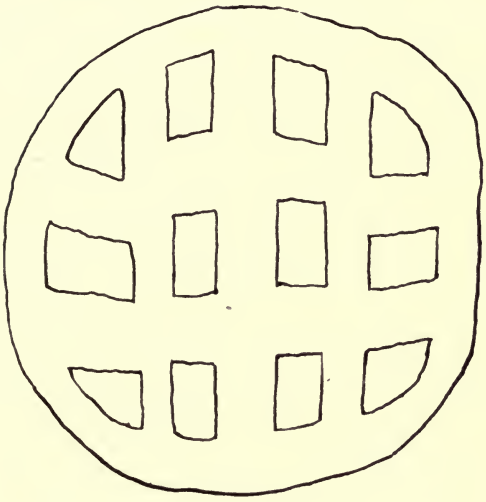

Fig. 4.

to exclude the air, which if admitted would hinder the regulation of the draft required for slow combustion.

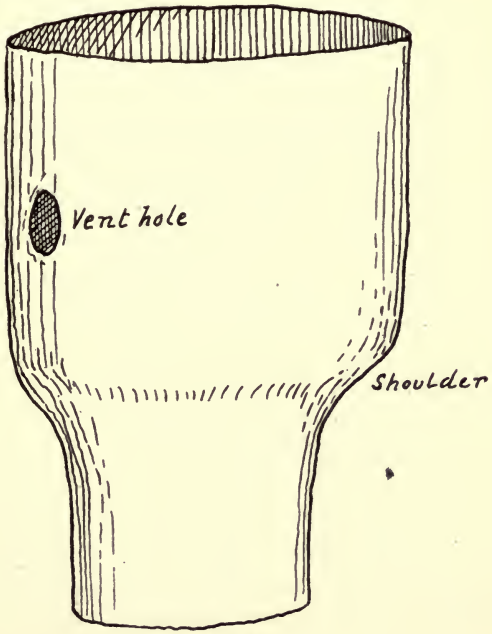

Fig. 5.

It takes 3 to 4 days to build, and as long to take down, a stack. The treatment requires 100 days of undisturbed chemical action. In the interval, nothing is done save the regulation of the ventilation. Each tier has a ventilating flue, 4 in. square inside and made of redwood. This flue leads to the top of the stack, where there is a valve, so that the temperature may be controlled, just like a furnace, which a stack really is, only on a very low scale of temperature, namely, 170 to 175° F. This temperature is maintained during 100 days and the success of the operation depends upon the maintenance of an equable warmth. If too hot, the acid evaporates rapidly and the lead escapes corrosion; if too cold, the process is too slow and time is wasted. About 50 tons of blue lead is put in each stack and this yields the quantity of white lead indicated by the formula. Of the original lead, 75 to 90% is corroded.

The method in use at the Selby works is the old Dutch process, which has been in use for at least 500 years. Formerly, that is, up to 30 years ago, manure was used, instead of tan. The manure had to be renewed at each operation, but the tan bark is employed repeatedly, only 20% of fresh tan being added each time. When the tan arrives it is red; after use it is black, for it becomes charred. The tan serves as a fuel that has the quality of burning extremely slowly and thus of yielding a low temperature for a lengthened period. The tan ferments when moistened with water; this fermentation is, in effect, combustion, and by it the water is turned into steam, heating the acid and accelerating chemical action. In decomposing—by oxidation—the tan, which is a form of carbon, throws off carbon dioxide. This and the acetic acid vapor produced by the action of the heat on the acid, attack the lead and yield a compound of lead carbonate and hydrated lead oxide, that is, white lead.

The chemical changes are expressed by the following formulas:

1. Lead oxide is formed, thus:

$$Pb+O=PbO$$

2. Hydrated lead oxide is formed:

$$Pb+H_2O+O=Pb(OH)_2$$

3. Lead oxide in presence of acetic acid (abbreviated symbol, $Ac=HC_2H_3O_2$) yields lead acetate and water, thus:

$$PbO+2HAc=PbAc_2+H_2O$$

4. Lead acetate and hydrated lead oxide combine, forming a basic acetate:

$$PbAc_2+Pb(OH)_2=PbAc_2.Pb(OH)_2$$

5. The basic lead acetate, $PbAc_2.2Pb(OH)_2$, reacts with carbonic acid gas in the presence of steam so as to form white lead, $Pb(OH)_2.2PbCO_3$, neutral lead acetate, $PbAc_2$, and water. These reactions cannot be expressed accurately by any known formula.

Thus in the final stage, the interchange of atoms produces the molecules necessary to continue the reaction. This explains why a very small quantity of acetic acid suffices to corrode a relatively large quantity of metallic lead. Only 0.3% acetic acid is needed, that is, 0.3 lb. acid will corrode 100 lb. lead, while if the reaction were a direct conversion from one substance into another there would be required 120 parts of acid to 207 parts of lead. The re-agents necessary in large quantity are CO_2 and H_2O, that is, tan and steam, both being produced from the moistened tan.

For a week or ten days the valves of the flues are kept open so as to create a draft and accelerate the combustion of the tan. Hot steam escapes from the top of the flues and is visible on a cool day. When uncovered the buckles are seen to have been changed from a blue metal to a white earthy substance, and when examined it is seen that the change has proceeded to a varying degree; most of the buckles are

corroded thoroughly, while others retain a thin nucleus of metallic lead.

The next operation is to separate the corrode from the uncorroded lead and grind it, to be ready for use as a white paint. When the chemical action in the 'stack' is completed, the top boards and uppermost layer of tan are removed. The pots are picked up by hand and (the acid having all evaporated) their contents are emptied into wheelbarrows, in which they are taken to a hopper, whence a bucket-elevator lifts the white residue to the top of the grinding-mill. The elevator discharges into a large revolving screen, called the 'rumbler', which resembles the trommel used in ore-milling. By the attrition to which it is subjected in this revolving screen, the white corrode is shattered, while the remnants of blue lead that have survived corrosion are flattened. The white lead goes through four or five of these hexagonal revolving screens of increasing fineness, gradating from ¼-inch apertures to the size of a pin-head, that is, one-fortieth of an inch. Besides the screening, the corrode is subjected to reduction by two pairs of rolls. In this process also the bits of blue lead are flattened and extended, while the white lead becomes subdivided by breaking until it is pulverized. This facilitates the separation of the one product from the other, the blue lead going back into the yard, to be re-melted, and cast into buckles.

Finally, the white lead passes through the finest of the screens, having brass wire-cloth with $^1/_{40}$-in. holes. Brass is used because iron or steel would be rusted by the trace of acetic acid remaining in the corrode, and any rust, of course, would contaminate the white lead, which comes from the last screen looking like corn meal. Next it goes into a cylindrical bin and thence into a pulverizer, the effect of which is to throw the particles against each other so as to break them by the force of collision. On the top of the pulverizer stands an inverted cone, 20 ft high, the bottom being 2 ft. diam. and the top 15 ft.

Inside of this there is a second cone, open at the top and with an outlet at the bottom. The outer cone has a tight cover, the only opening being in the centre, where there is an escape through a pipe attached tight cover, the only opening being in the centre, to a suction fan. (See Fig. 6.) As soon as the particles of white lead are fine enough to be carried in suspension they fly upward and outward between

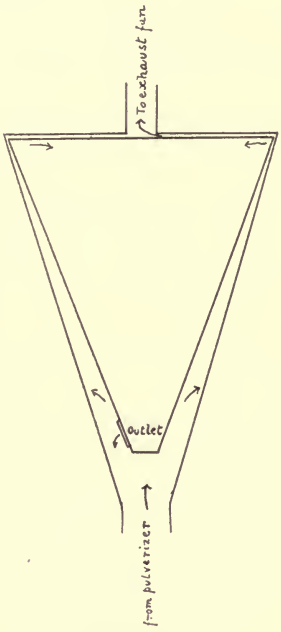

Fig. 6.

the two cones, which are 18 in. apart at the bottom and only half an inch apart at the top. The white-lead dust has to rise 20 ft. and fly horizontally 7 ft. before it reaches the outlet, in a stream only half an inch deep. If it is not sufficiently pulverized to be able to do thus, it falls back into the pulverizer for further comminution. This method of sizing in air is very different from, and much more effective than, the old way of separation in water. It is the invention of the superintendent of the white lead plant,

which is the property of the National Lead Co. of California, while the smelter adjoining belongs to the Smelter Securities Corporation, a subsidiary of the American Smelting & Refining Company.

The fan above the cones is run at such a speed and the pulverizer is so regulated as to give a product that will pass through a silk cloth of 200 mesh or 40,000 apertures per square inch. Such a cloth will hold water for a while, that is the water will not break through until its surface tension is overcome. The silk comes from Grenoble, in France. From the fan the white lead passes to a cyclone collector, which is well named, for the draft makes a cyclone, the dust being blown into the top of a cylindrical tank with a conical bottom, so that the powdered white lead falls at the centre of the whirl, where a quiet eddy abates the centrifugal force. Thus it descends into a storage bin, ready to be packed dry or mixed with oil.

To eliminate the last trace of acetic acid, the air that goes through the fan is first ozonized by being passed through a silent electric discharge of 5000 volts. The ozonized air has a decided smell, as of mountain air or the atmosphere after a thunder-storm. Ozone is a strong oxidizer and destroys any surviving particles of tan or acetate of lead. The excess of air from the pulverizer is laden with dust, that is, minute particles of white lead. To clear it, this dust-laden air is passed through 200 canvas bags, each 8 in. diam. and 40 ft. long, arranged in vertical series. These allow the air to escape through the canvas while retaining the dust, so that an extremely fine product is saved by this operation.

We have now followed the white lead to the bin underneath the cyclone collector. From this bin the product is put into a truck and then shoveled into a mixer, which is a revolving pan having a stirrer on one side. Here the proper quantity of linseed oil is added. The lead and the oil are mixed for 20 to 30 minutes. Then the valve in the centre of the pan is

raised and the white lead passes into a receiver; this feeds the stones, where the white lead is ground with oil. The oil is refined linseed oil made from flax-seed grown in Idaho and Washington. The seed is crushed between rolls and then placed under a hydraulic press (6000 lb. per sq. in.), so that the natural oil is squeezed out. It is then refined by filtering and settling. The oil used at Selby is supplied by the Pacific Oil & Lead Co. of San Francisco, a branch of the American Linseed Oil Co. But if the white lead is to be packed dry, it is put into an ordinary flour barrel, which holds 800 lb. of white lead, as compared to 198 lb. of flour.

From the receiver the white lead drops into the eye or centre of a pair of oil-stones. These are French buhr-stones, the lower one revolving, while the upper is stationary, so that the lead has to pass between the two surfaces, which are pressed hard against each other. The white lead works its way to the edge of the stones and drops to the centre of another pair, the rotary motion again causing the product to travel from the centre to the edge, where it falls into a cooler, the white lead in the course of grinding having become warm (about 150°F). This cooler is a water-jacketed fixed brass pan with three revolving arms, which aerate the lead and move it to an outlet leading to a small hopper. The hopper empties into the kegs, as they are placed underneath by an operator. A keg 12 in. high and 10 in. diam. will contain 100 lb. lead in oil. The keg is filled while it is being weighed. White lead is sold in kegs of various sizes holding from 12½ to 300 lb. each. The kegs are made at St. Louis; the wood is oak. For this purpose the Californian oak is unsuitable, being too porous. The bungs are made of poplar, which is soft and does not split. A label is affixed with glue and this moisture causes the bung to expand so as to fill the aperture snugly. The label of the Selby works is in blue and gold, the colors of the University of California.

The plant is run by electricity, there being a separate motor for each part of the process. The current is supplied by the Bay Counties Power Co., from a generating station at Colgate, in Yuba county, 140 miles distant. The transmission of power involves crossing the Straits of Carquinez, a short distance above Selby, where the estuary of the Sacramento is 2750 ft. wide. Two towers carry the line; that on the north side of the Straits is 225 ft. high on a bluff 160 ft. above the water, and the one on the south side near Crockett, is 64 ft. high, at an altitude of 300 ft. The span, from tower to tower, is 4427 ft. long.

The smelting operations are under the direction of E. N. Engelhardt, as manager, with F. C. Newton, as assistant. The superintendent of the white lead plant is J. P. Neville. Thus a Russian, an American, and an Englishman unite in manufacturing the pigment, and just as the various substances required in the making of white lead come from localities widely separated, so the intelligence that applies them usefully is contributed by diverse nationalities.

From Selby the white lead is transported on a barge or steamer to the Navy Yard at Mare Island, which is less than a mile distant. Dry pigment is preferred for use at sea because oil renders it more subject to deterioration. Paint and oil are always placed in 'the eyes of the ship,' that is, the forepeak, right in the bow. Here there is a space that is useless for other purposes; it is fitted with shelves, tanks for linseed oil, and other ingredients. The fire-plug is always put in 'the bows', as a protection. But if the paint is to be used at once, the white lead already mixed with oil is purchased by the Bureau of Supplies & Accounts of the Navy Department, the price being 6 cents per pound. After arrival at the Navy Yard the white lead is mixed according to formula, the first coat contining considerably more lead than the last. This is done because lead is an excellent preservative against the weather and gives

A Cruiser in Dry-Dock at Mare Island Receiving a Coat of Paint.

a good body for the first coat; if it were used in the final coat without a large proportion of white zinc, the surface of paint would soon acquire a dirty yellow hue. The following are the official specifications for the white lead purchased by the Navy Department.

SPECIFICATIONS FOR WHITE LEAD,

ISSUED BY THE

BUREAU OF SUPPLIES AND ACCOUNTS, NAVY DEPARTMENT,
OCTOBER, 1902.

SUPERSEDING SPECIFICATIONS ISSUED JANUARY, 1901.

Must be of the best quality, finely ground in pure well-settled raw linseed oil; must be of maximum whiteness; must work freely under the brush, and not be crystalline in structure nor deficient in density and opacity; must not contain more than 0.5 per cent of moisture, and as best commercial grades of white lead contain acetates equivalent to less than one-tenth of 1 per cent of glacial acetic acid, under no circumstances will white lead be accepted which contains acetate in excess of fifteen one-hundredths of 1 per cent of glacial acetic acid. Dry pigments must contain at least 98 per cent of hydrate carbonate of lead. Its working under the brush, maximum whiteness, body, and covering qualities to be determined by practical test.

GENERAL PAINT SPECIFICATIONS.

The pigment must be of the best quality, finely ground in pure well-settled linseed oil (unless otherwise specified) to a medium stiff paste which will break up readily in thinning, and must be free from barytes or other adulterants. The shade, fineness, and tone must in each case be in strict accordance with samples to be seen upon application to the general storekeeper.

Packing.—In all cases where paints, etc., are purchased in *metal* packages they are to be boxed in quantities of 100 pounds each; the cases to be made of ⅞-inch new pine, planed on the outside. Tin pails or cans (commercial packages) of 12½, 25, and 50 pounds are to be provided with bails.

It may be mentioned that each vessel has a certain allowance of paint given her every six months. The

flanges of piping for steam, exhaust, ventilation, fresh water, and salt water, etc., all have to be painted with different colors, for easy identification. To suggest the quantity of lead consumed, it may be stated that an ordinary 30-ft. racing cutter, if painted for service, would require 150 lb. of paint. Just previous to a race, every particle of this is scraped from the boat, thus removing what would be equal to the weight of an extra man.

Zinc white is mixed with the lead as a preservative. Zinc white, or zinc oxide, is obtained by a process, the essentials of which were worked out by Samuel Wetherill in 1851; this consists in mixing the roasted ore with fuel (anthracite or coke), and bedding it 3 or 4 ft. thick upon a hearth made of perforated cast-iron plates. The furnace door is closed and cold air blown under the grate. The zinc is volatilized as metal, but immediately oxidizes to a fume, which is collected from the smoke by passing it through muslin bags. The fume so collected requires to be subsequently refined. Zinc white of pure grade is also made in one operation by distilling metallic zinc, or commercial spelter, placed in fire-clay retorts on the hearth of a reverberatory furnace, the light flaky oxide being readily carried off in the draft, and caught in collecting chambers of large dimensions. Another method, employed in France, is to expose metallic zinc to the action of superheated steam. Zinc oxide is formed, with the evolution of hydrogen, which may be mixed with carburetted gases to form an illuminating gas of high heating power. The great advantage of zinc white over white lead is that sulphur gases in the atmosphere will not discolor it, whereas with white lead a black lead sulphide is formed.

The drying of paints, varnishes, and oils means the oxidation of the medium with which they are mixed by means of some substance that will readily yield up oxygen, such as lead oxide (litharge) or manganese dioxide. Boiled linseed oil is commonly employed for this purpose, it having been boiled with one or the

other of the above-named substances, whereby a portion of the oil is oxidized, and an amount of the oxidizing agent is dissolved and slowly continues the reaction in the oil. The effect of oxidation of the oil is to convert it into a permanent leathery material, which resists the action of the weather. It is this behavoir of linseed oil in the presence of a 'drier' or oxidizer that makes it suitable as a medium for spreading pigments upon wood and iron. Turpentine also oxidizes readily, and does not dissolve mineral substances, nor react with them chemically, but it is a solvent for the leathery product of oxidation of boiled linseed oil, and it also mixes with the oil, which it will not do with water or most liquids. Hence it is useful as a 'thinner' for paints, without impairing their quality, or checking their rate of drying.

The following are the instructions issued by the Navy Department relative to the painting of vessels:

INSTRUCTIONS RELATIVE TO PAINTING NAVAL VESSELS.

1. The quantity of the different paint materials given in the allowance is calculated on the number of square yards of surface to be painted and the number of coats to be applied. The number of square yards of painting surface for different paints is to be inserted in table at the time of the preparation of the allowance.

2. The quantity of oil and turpentine sufficient to mix a given amount of paint varies. If the paint is newly manufactured it will require less, and if there be a high temperature it will also require less, but the quantities given in the formulas may be considered a fair proportion, and such as will insure good drying.

3. Paint should be used as soon as it is mixed, and therefore should not be prepared in larger quantities than may be required for the work in hand. The drying qualities of all paints are injured if kept mixed in store-rooms for any considerable time. Surplus mixed paint should be carefully protected from the air, and used on the first opportunity, with a little turpentine added.

4. The surface of the work to be painted should be thoroughly cleaned and dry before the paint is applied.

Photograph by Turrill & Miller.

The Cruiser California in the Bay of San Francisco.

5. Brushes after being used should be rubbed out and immediately placed in water and kept there until required again.

6. In painting all pipes aboard the vessel, the standard colors for piping as issued by the Bureau is to be adhered to for the different piping systems.

7. In the preparation of the allowance list of paints, additional colors and paints will be allowed for the painting of such articles and fixtures as would not be coated by any of the formulas hereafter given.

WHITE PAINT FOR OUTSIDE WORK.

Formula for mixing 1 gallon.

No. 1.

White lead in oil	pounds	7
White zinc in oil	pounds	7
Raw linseed oil	gallon	½
Turpentine	gills	2
Japan drier	gill	1

No. 2.

White lead in oil	pounds	5
White zinc in oil	pounds	9
Raw linseed oil	pints	3
Turpentine	gills	4
Japan drier	gill	1

This paint is to be applied to all work exposed to the weather, including outside of hull from load water line to rail; inside of waist; under break of forecastle and poop decks; and on the inside and outside of boats.

When the paint is in such condition as to require two coats, formula No. 1, as given above, should be used for the first coat, and formula No. 2 for the second coat. When only one coat is required, formula No. 2 should be used.

WHITE PAINT FOR INSIDE WORK.

Formula for mixing 1 gallon.

White lead in oil	pounds	7
White zinc in oil	pounds	7
Raw linseed oil	gallon	¼
Turpentine	gallon	¼
Japan drier	gill	1

This paint is used for painting crew's spaces, store-rooms, magazines, and dynamo-rooms, inside pilot-house, etc.

If old work is in good condition one coat is sufficient; if in bad, two coats should be applied.

FLAT WHITE

Formula for mixing 1 gallon.

No. 1.—For officers' quarters (white).

French white zinc	pounds	8
White lead	pounds	9
Turpentine	pints	3
Raw linseed oil	gill	1
Japan drier	gill	½

No. 2.—For officers' quarters (flat white).

French zinc	pounds	17
Turpentine	pints	3
Japan drier	gill	½

When the paint is in bad condition, having turned yellow or worn with age, it should be given one coat of white paint as per formula No. 1, then one coat as per formula No. 2 (flat white). If the work is in fair condition and only requires one coat of paint, formula No. 2 (flat white) should always be used. Formula No. 2 should be mixed as above in the afternoon, run through a seive to get out all lumps, skins, etc., top of vessel covered and placed aside until next morning, when all oil or liquid found floating on top of paint should be dipped off. If the paint should be found too thick, after stirring, to work free and spread well under the brush, a small quantity of clear spirits of turpentine should be added.

The quantity of different paints required to cover 100 square yards of surface one coat is as follows:

Weather work, white	gallons	3¼
Inside work, white	gallons	2½
Flat white	gallons	1¾

And thus finally we have followed the white lead from the ore broken in the mine in northern Idaho to the Navy Yard at Mare Island, where it is laid upon the sides of the battleship. But one more agent is necessary to finish this highly complex technical process; that agent is the sunlight of California. Navy men will tell you that the painting of vessels in the ports of Puget Sound is hindered by the dampness of the climate and that the sulphurous smoke of other localities will blacken the fresh paint. At Mare Island the painting proceeds under most favorable conditions, for the air is pure and sunny, so that the paint dries without hindrance. Thus many lands and many States contributed to the manufacture of

the paint that not only decorates the battleship but also preserves its steel structure from the corrosive effects of wind and weather. We have seen that some one ingredient or device has come from France, Australia, New York, Missouri, Alabama, Washington, Idaho, Nevada, and California, but the final touch was given by the warm pure sunlight of California.

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